IS 6849-3 (1976): Methods of measurement of the performance characteristics of positive-displacement vacuum pumps, Part 3: Water vapour pumping capacity [MED 17: Chemical Engineering Plants and Related Equipment]

BLANK PAGE

IS : 6849 (Part III) 1976

(Reaffirmed 2003)

Indian Standard

METHODS OF MEASUREMENT OF PERFORMANCE CHARACTERISTICS OF POSITIVE-DISPLACEMENT VACUUM PUMPS

PART III WATER VAPOUR PUMPING CAPACITY

(First Reprint MAY 1984)

UDC 621·522 : 532·575

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4 *April* 1977

Indian Standard

METHODS OF MEASUREMENT OF PERFORMANCE CHARACTERISTICS OF POSITIVE-DISPLACEMENT VACUUM PUMPS

PART III WATER VAPOUR PUMPING CAPACITY

Chemical Engineering Sectional Committee, EDC 57

Chairman	*Representing*
Dr O. P. Kharbanda	Larsen & Toubro Ltd, Bombay
Members	
Shri P. M. Mehta (*Alternate* to Dr O. P. Kharbanda)	
Dr K. Aghoramurthy	Indian Petrochemicals Corporation Ltd, P. O. Jawaharnagar
Shri M. V. Naik (*Alternate*)	
Shri A. K. Basu	Indian Institute of Chemical Engineers, Calcutta
Dr A. S. Bhaduri (*Alternate*)	
Dr B. K. Bhattacharjee	I. C. I. (India) Private Ltd, Calcutta
Dr T. Guha (*Alternate*)	
Shri M. R. Bhattacharjee	The A. P. V. Engineering Co Private Ltd, Calcutta
Shri B. Banerjee (*Alternate*)	
Shri S. N. Bhattacharya	Tata Chemicals Ltd, Mithapur
Shri A. N. Taskar (*Alternate*)	
Shri A. K. Bose	Directorate General of Technical Development, New Delhi
Shri A. B. Mallick (*Alternate*)	
Dr K. S. Chari	Fertilizer Association of India, New Delhi
Shri R. Sadagopa Chari	Bharat Refineries Ltd, Bombay
Shri S. L. Aranha (*Alternate*)	
Shri P. T. Cherian	Oil and Natural Gas Commission, Dehra Dun
Shri B. R. Choudhury	Engineer's India Ltd, New Delhi
Dr R. Krishnamurty (*Alternate*)	
Shri R. L. Dalal	Dalal Consultants & Engineers Pvt Ltd, Bombay
Shri R. Jaishankar (*Alternate*)	
Dr L. K. Doraiswamy	Council of Scientific and Industrial Research, New Delhi
Shri M. V. Kunte (*Alternate*)	
Shri A. Dutta Mazumdar	Fertilizer Corporation of India Ltd, New Delhi
Shri N. K. Seturam (*Alternate*)	
Dr H. E. Eduljee	Indian Chemical Manufacturers' Association, Calcutta
Shri J. N. Goswamy	Lloyd's Register of Shipping, Bombay
Shri H. T. Pavri (*Alternate*)	

(*Continued on page* 2)

(Continued from page 1)

Members	*Representing*
Shri J. P. Kapur	Indian Chemical Manufacturers' Association, Calcutta
Shri R. Kalidas (*Alternate*)	
Dr M. G. Krishna	Indian Institute of Petroleum (CSIR), Dehra Dun
Shri H. K. Mulchandani (*Alternate*)	
Shri K. Manivanan	Directorate of Industries, Government of Haryana, Chandigarh
Shri B. B. Mathur	Delhi Cloth & General Mills Co Ltd, Delhi
Shri I. B. Lal (*Alternate*)	
Shri R. C. Misra	Bharat Heavy Electricals Ltd, Bhopal
Shri K. Mukherjee	Walchandnagar Industries Ltd, Bombay
Shri R. C. Rathi (*Alternate*)	
Shri S. K. Nayak	Indian Oil Corporation Ltd (Refineries Division), New Delhi
Shri K. C. Jain (*Alternate*)	
Shri P. K. Pai	Hindustan Petroleum Corporation Ltd, Bombay
Shri H. B. Desai (*Alternate*)	
Shri R. V. Raghavan	Vijay Tanks & Vessels Pvt Ltd, Bombay
Shri A. B. Rai	DE SMET (India) Pvt Ltd, Bombay
Shri M. L. Kachru (*Alternate*)	
Dr N. Rajasekharan	Pennwalt India Ltd, Bombay
Shri J. S. Kaul (*Alternate*)	
Shri A. P. Rao	Bharat Heavy Plate & Vessels Ltd, New Delhi
Shri M. Venkataratnam (*Alternate*)	
Shri V. K. Rao	Ion Exchange (India) Ltd, Bombay
Shri A. K. Chathurvedi (*Alternate*)	
Shri V. M. Rao	K. C. P. Ltd, Madras
Shri K. Sambasiva Rao (*Alternate*)	
Shri D. S. Sastry	Hindustan Organic Chemicals Ltd, Bombay
Shri D. D. Sharma	The Indian Sugar & General Engineering Corporation, Yamunanagar
Shri N. K. Gupta (*Alternate*)	
Dr J. K. N. Sharma	National Physical Laboratory (CSIR), New Delhi
Shri S. Subbiah	Directorate General of Supplies & Disposals, New Delhi
Dr V. C. Thakar	Associated Cement Companies Ltd, Bombay
Shri A. K. Misser (*Alternate*)	
Dr Y. Venkatesham	National Research Development Corporation of India, New Delhi
Dr D. S. Viswanath	Indian Institute of Science, Bangalore
Dr P. K. Deshpande (*Alternate*)	
Shri S. N. Wazir	Metallurgical and Engineering Consultants (India) Ltd, Ranchi
Shri N. M. Manchanda (*Alternate*)	
Shri S. Chandrasekharan, Deputy Director (Mech Engg)	Director General, ISI (*Ex-officio Member*)

Secretary

Shri Gurcharan Singh
Assistant Director (Mech Engg), ISI

(Continued on page 12)

Indian Standard

METHODS OF MEASUREMENT OF PERFORMANCE CHARACTERISTICS OF POSITIVE-DISPLACEMENT VACUUM PUMPS

PART III WATER VAPOUR PUMPING CAPACITY

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 22 December 1976, after the draft finalized by the Chemical Engineering Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 This standard has been prepared to ensure that the measurement of performance characteristics of positive-displacement vacuum pumps are, as far as possible, carried out under uniform conditions. It is hoped that, as a result, measurements conducted by different manufacturers or in different laboratories and statements of performance quoted in manufacturer's literature would be on a comparable basis to the benefit of both the user and the manufacturer.

0.3 This standard is being issued in parts. This part covers the measurement of the water vapour pumping capacity of positive-displacement vacuum pumps. The measurement of the volume rate of flow (pumping speed) has been covered in Part I, and the measurement of ultimate pressure has been covered in Part II of this standard.

0.4 International system (SI) units have been used in the standard. For guidance, the relationship of these units to other units is given below:

$$1 \text{ pascal (Pa)} = 1 \text{ newton/square metre}$$
$$= 7{\cdot}5 \times 10^{-3} \text{ torr}$$

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard specifies the method for determining the water vapour pumping capacity of positive-displacement vacuum pumps (for example, gas-ballast pump).

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions, in addition to those given in IS : 4110-1967*, shall apply.

2.1 Water Vapour Tolerance — The highest (intake) pressure at which a pump under normal ambient conditions (27°C, 101 kPa), shall pump and exhaust water vapour in continuous operation.

2.2 Water Vapour Pumping Capacity — The maximum mass of water in grams which a pump shall pump and exhaust in the form of water vapour per hour in continuous operation under normal ambient conditions (27°C, 101 kPa). The water vapour capacity may be calculated from the water vapour tolerance as specified in **4.1**.

3. MEASUREMENT OF WATER VAPOUR TOLERANCE

3.1 Test Dome — For the measurement a stainless steel test dome as shown in Fig. 1 shall be used; its volume shall be at least 5 times the chamber volume of the pump under test. The chamber volume is the nominal pumping speed per hour divided by the number of revolutions per hour and the number of intake strokes per revolution. The connection to the inlet port of the pump shall consist of an adaptor, the length of which should not exceed the dimension 0·5 *D*. The test dome may be mounted in a horizontal or vertical position. The appropriate dome dimensions for pumps of given size are indicated in Table 1.

3.2 Method of Measurement — The maximum amount of water carried with the exhaust gas at 100 percent saturation is measured and this quantity is considered to be equal to the maximum quantity which may be pumped in continuous operation. The maximum amount of water carried by the exhaust gas is calculated from the amount of gas-ballast air and the temperature of the exhaust gas. The temperature of the exhaust gas and the amount of gas-ballast shall be measured at the intake pressure corresponding to the water vapour tolerance. In order to arrive at this pressure several measurements in the sense of an approximation method are required. Instead of water vapour, the pump is allowed to pump ambient air during measurement, whereby related to the same intake pressure approximately the same exhaust gas temperatures are obtained, if necessary, after corresponding correction.

*Glossary of terms used in high vacuum technology.

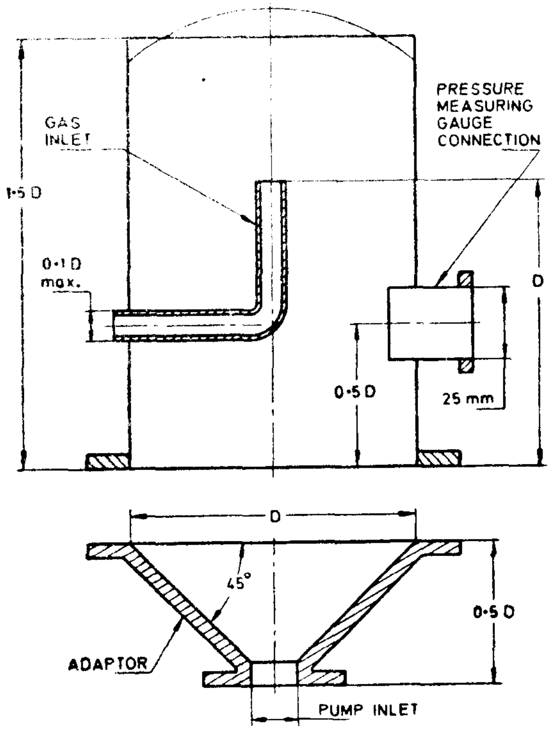

FIG. 1 RECOMMENDED FORM OF TEST DOME

TABLE 1 DOME DIMENSIONS FOR PUMP TESTING

(*Clause* 3.1, and *Fig.* 1)

VOLUME SWEPT PER COMPRESSION CYCLES IN LITRES V_p (1)		VOLUME OF TEST DOME IN LITRES V_D (2)	INTERNAL DIAMETER OF TEST DOME mm D (3)
From 0 up to and including	0·26	1·3	100
Over 0·26 ,, ,, ,,	1·1	5·4	160
,, 1·1 ,, ,, ,,	4·2	21	250
,, 4·2 ,, ,, ,,	17	84	400
,, 17 ,, ,, ,,	65	325	630
,, 65 ,, ,, ,,	260	1 300	1 000

3.3 Gauges

3.3.1 *Thermometers* — For measuring the temperature of the exhaust gas and the ambient air, instruments such as mercury thermometers, resistance thermometers and the like, are used. The error of these instruments shall not exceed ± 0·5°C.

The measurement of the exhaust gas temperature is carried out in a tubular bend according to Fig. 2. Dimension *D* should be equal to the nominal width of the exhaust port of the pump, but should not be smaller than 20 mm. The temperature sensing device should be fitted at the location as indicated in such a way that the measured values are not appreciably affected by heat conduction.

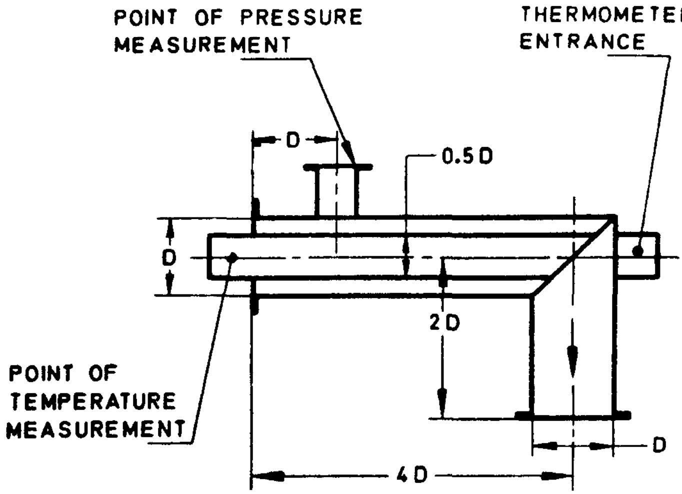

FIG. 2 TEMPERATURE MEASUREMENT ASSEMBLY FOR EXHAUST

3.3.2 *Pressure Gauges* — The intake pressure should be measured by means of a U-tube manometer or a calibrated diaphragm manometer, the error of which shall not exceed 5 percent of the pressure to be measured.

The gauges should be connected to the test dome as indicated in Fig. 1, without an intermediate cold trap. The pressure difference between the exhaust flange of the pump and the ambient atmosphere shall be measured with a U-tube manometer having an accuracy of ± 133 Pa.

3.3.3 *Gas-Ballast Metering Device* — For measuring the amount of gas-ballast a gas-meter having an accuracy of ± 1 percent or a float type meter shall be used.

3.4 Procedure of Measurement — The measuring set-up of the gauges is shown in Fig. 3. The pump under consideration is to be run with the variable-leak valve closed and the gas-ballast valve fully open for an adequate length of time, that is, until the increase of temperature as measured at the specified point in the exhaust is less than 0·5°C, within 15 minutes. The final temperature measured is the temperature of the exhaust gas, t. This procedure should be carried out for at least four different intake pressures in the test dome as equally stepped as possible. At least one of these intake pressures should be higher than the water vapour tolerance to be expected. For each intake pressure the following data shall be measured:

End temperature of the exhaust gas	t°C
Intake pressure	p kPa
Ambient temperature	t_R°C
Amount of gas-ballast	B m^3 h^{-1}

Measurements are only permissible if the atmospheric pressure is between 96 kPa and 107 kPa. In addition, care shall be taken that the pressure difference between the exhaust pressure and atmospheric pressure does not exceed 1·33 kPa. If the pressure difference exceeds 1·33 kPa the exhaust line is too restrictive and should be changed.

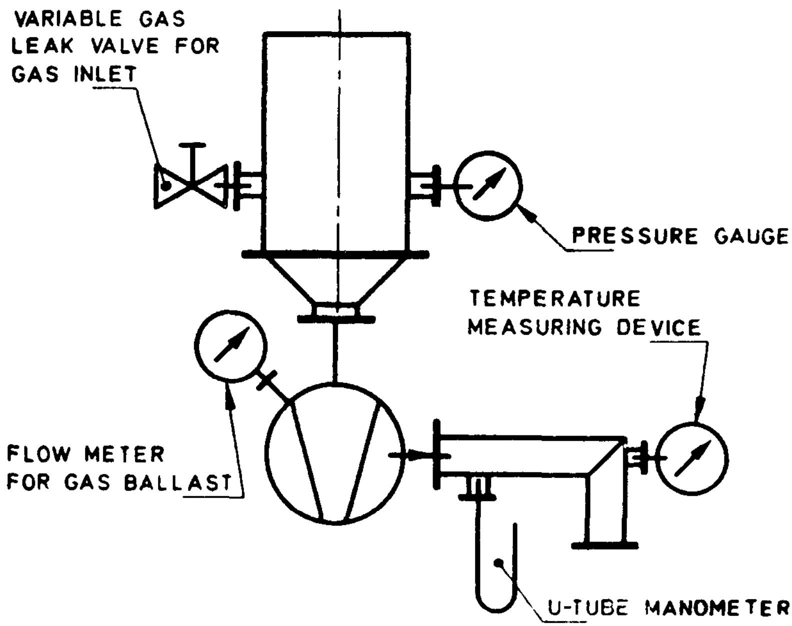

FIG. 3 EXPERIMENTAL SET-UP FOR DETERMINATION OF WATER VAPOUR PUMPING CAPACITY

3.5 Rotational Speed — In all the tests given above the actual rotational speed of the pump shall not deviate more than ± 3 percent from that specified by the supplier of the pump.

3.6 Evaluation of Measurements — The measured exhaust gas temperature, t shall be reduced by the difference between the ambient temperature t_R, as measured and the ambient temperature of 27°C to which the water vapour tolerance is being related. In addition, a correction shall be made for the temperature t_R of the pumped air at the intake, if t_R deviates from the vapour saturation temperature t_s, which is a function of the intake pressure p as shown in Fig. 4.

The exhaust gas temperature required in the course of further evaluation is given by the formula:

$$t_0 = t - (t_R - 27^\circ\text{C}) + \frac{t_s - t_R}{1 + \frac{B \times 101}{S \times p} \times \frac{5}{6}} \qquad \ldots\ldots(1)$$

S is the speed of the pump at the intake pressure p, in accordance with the speed characteristic of the pump, with gas ballast opened. The speed of the pump S, shall be determined in accordance with IS : 6849 (Part I)-1973*. For B and S the same units shall be used. The values for t_0 as a function of intake pressure p shall be plotted as in Fig. 5 (line *A-B*) as well as the values for the relation B/S as function of the intake pressure (line *C-D*).

The ratio of gas-ballast to pump speed at intake pressure (which approximately corresponds to the water vapour tolerance) shall then be calculated as a dimensionless number. The ordinate of point E which is the point of intersection of line *A-B*, $p_w = f (t_0)$ and the curve representing the relation $\frac{B}{S}$ is the water vapour tolerance p_w. Values of $\frac{B}{S}$ may be interpolated between the curves (*see* Fig. 5).

For $\frac{B}{S} = 0.105$, the water vapour tolerance p_w is given by the point of intersection (E) of the line *A-B* with the relevant curve (*see* Fig. 5).

*Methods of measurement of the performance characteristics of positive-displacement vacuum pumps: Part I Measurement of the volume rate of flow (pumping speed).

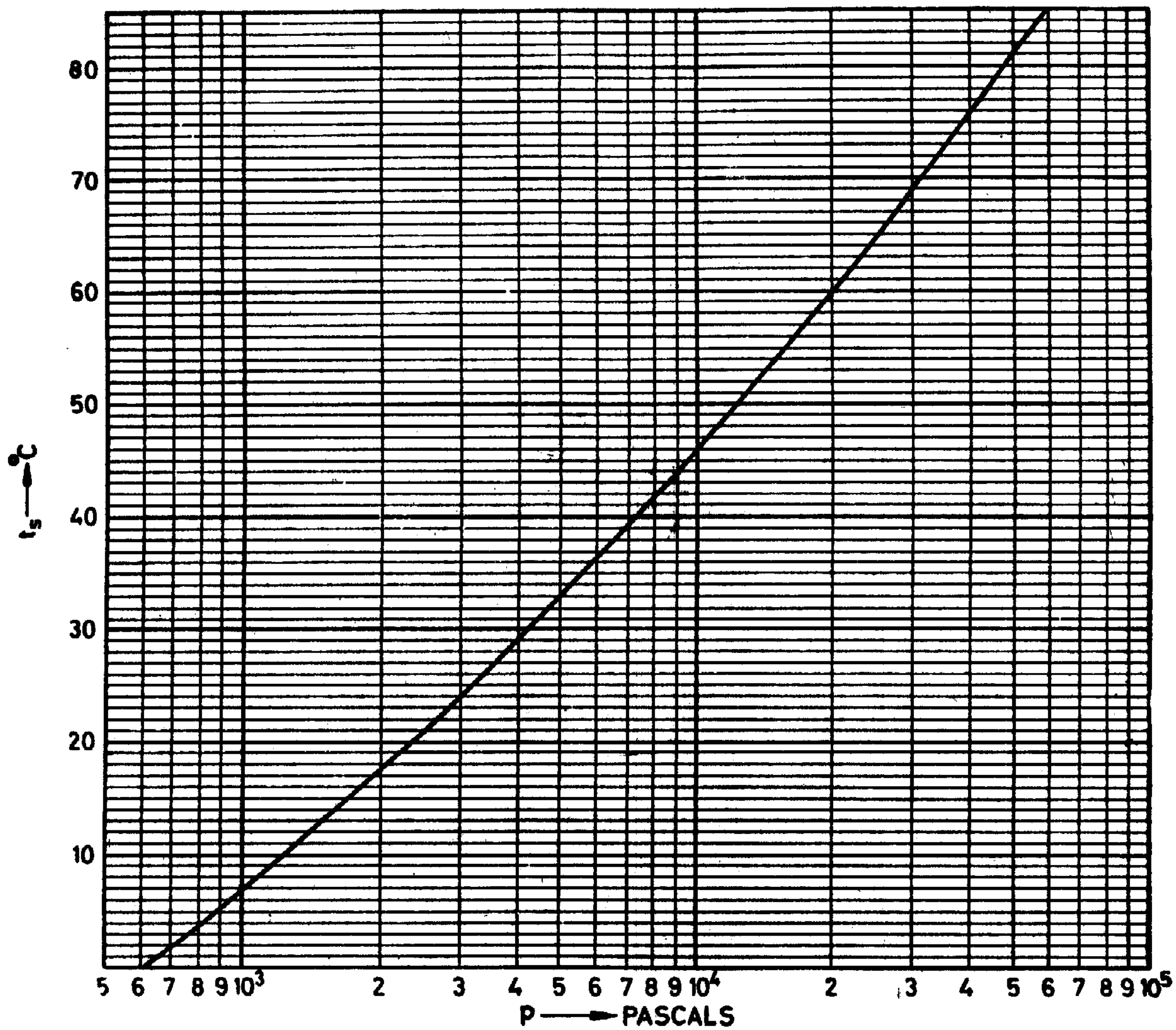

FIG. 4 SATURATED WATER VAPOUR PRESSURE AT DIFFERENT TEMPERATURES

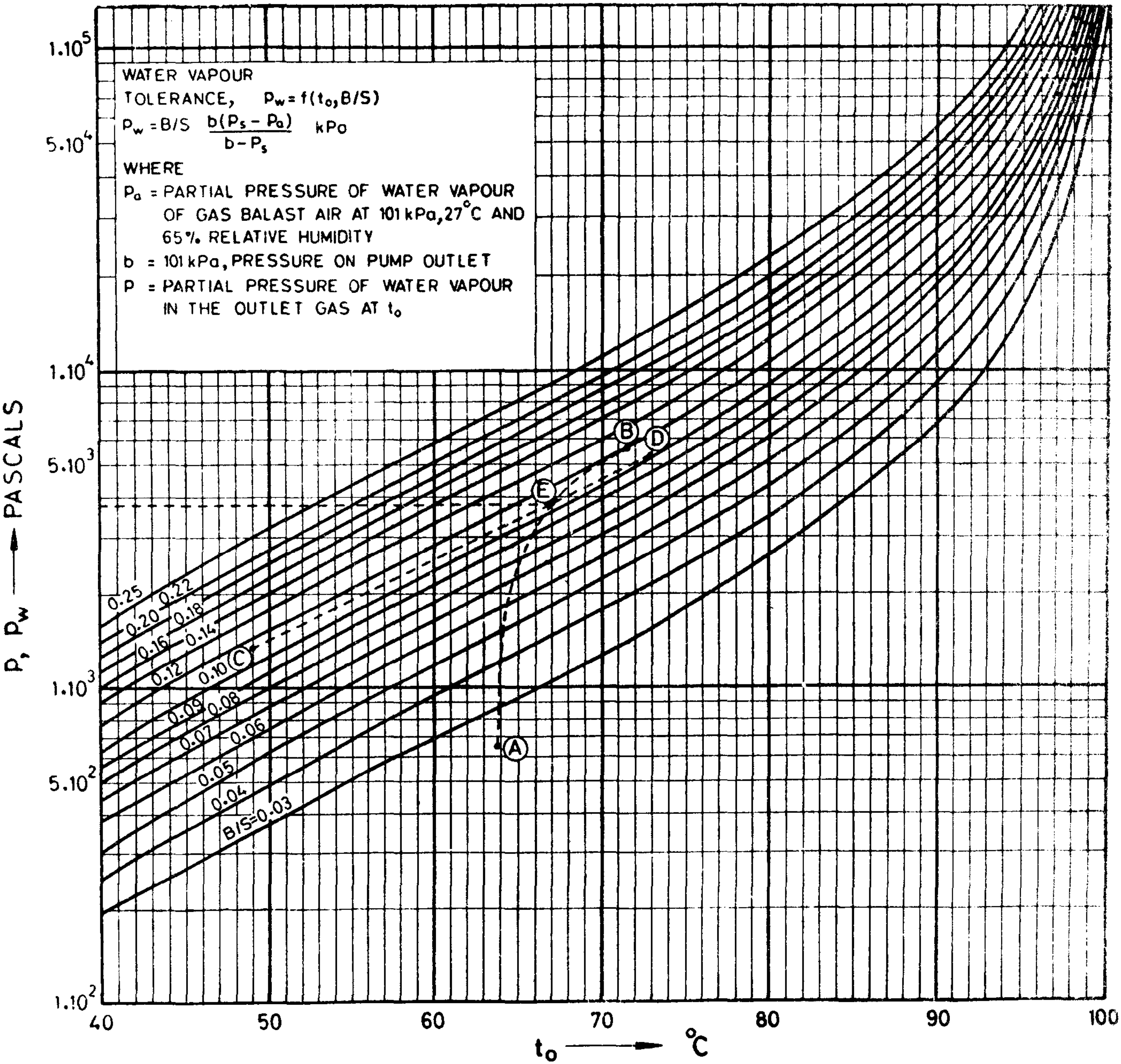

Fig. 5 Curves for Water Vapour Tolerance at Different Temperatures

4. WATER VAPOUR CAPACITY

4.1 For calculating the water vapour capacity c_w from the water vapour tolerance p_w the following formula is used:

$$c_w = S\left(\frac{0{\cdot}86}{0{\cdot}133} p_w + 2\right) \mathrm{g\ h^{-1}} \qquad \text{.................................(2)}$$

The speed of the pump at the intake pressure p_w, expressed in kilopascals, shall be taken from the speed characteristic, when the pump is gas-ballasted and S is expressed in $\mathrm{m^3\ h^{-1}}$

4.2 The formula in **4.1** is sufficiently accurate for water vapour tolerances between 1·33 kPa and 8·00 kPa. Otherwise, standard tables for water vapour pressures at various temperatures shall be used.

(*Continued from page* 2)

Panel for Standardization of Vacuum Equipment, EDC 57/P-2

Convener	*Representing*
DR J. K. N. SHARMA	National Physical Laboratory (CSIR), New Delhi
Members	
DR S. S. S. AGARWALA	Central Electronics Engineering Research Institute (CSIR), Pilani
SHRI C. AMBASANKARAN	Bhabha Atomic Research Centre, Bombay
SHRI P. VIJENDRAN (*Alternate*)	
SHRI BIJAN KUMAR DUTTA	Basic & Synthetic Chemicals Pvt Ltd, Calcutta
SHRI BIMALENDRA NATH CHAKRABORTY (*Alternate*)	
SHRI S. V. NARASAIAH	Hind High Vacuum Co (P) Ltd, Bangalore
SHRI V. K. V. RAJU (*Alternate*)	
SHRI R. RAMABRAHMA	Toshniwal Bros Pvt Ltd, Madras
SHRI D. J. RAO (*Alternate*)	
SHRI B. S. RAMAPRASAD	Indian Institute of Science, Bangalore
DR E. S. VISWANATH (*Alternate*)	
SHRI S. C. RANADIVE	J. B. Sawant Engineering Pvt Ltd, Bombay
DR B. K. SARKAR	Vikram Sarabhai Space Centre, Trivandrum
SHRI R. V. PERUMAL (*Alternate*)	
SHRI G. V. SATHE	Vacuum Plant & Instruments Mfg Co Pvt Ltd, Mundhawa
SHRI R. R. KARANDIKAR (*Alternate*)	
SHRI V. P. SUNDERSINGH	Indian Institute of Technology, Bombay
DR S. R. JAWALEKAR (*Alternate*)	
SHRI VED PRAKASH	Vacuum Instruments Company, New Delhi

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 $kg.m/s^2$
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

INDIAN STANDARDS INSTITUTION

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002

Telephones : 26 60 21, 27 01 31 Telegrams : Manaksanstha

Regional Offices :

			Telephone
Western	: Novelty Chambers, Grant Road	BOMBAY 400007	89 65 28
Eastern	: 5 Chowringhee Approach	CALCUTTA 700072	27 50 90
Southern	: C. I. T. Campus	MADRAS 600113	41 24 42
Northern	: B69, Phase VII	S.A S. NAGAR (MOHALI) 160051	8 78 26

Branch Offices :

'Pushpak', Nurmohamed Shaikh Marg, Khanpur	AHMADABAD 380001	2 03 91
'F' Block, Unity Bldg, Narasimharaja Square	BANGALORE 560002	22 48 05
Gangotri Complex, Bhadbhada Road, T.T., Nagar	BHOPAL 462003	6 27 18
22E Kalpana Area	BHUBANESHWAR 751014	5 36 27
5-8-56C L.N. Gupta Marg	HYDERABAD 500001	22 10 83
R 14 Yudhister Marg, C Scheme	JAIPUR 302005	6 98 32
117/418 B Sarvodaya Nagar	KANPUR 208005	4 72 92
Patliputra Industrial Estate	PATNA 800013	6 28 08
Hantex Bldg (2nd Floor), Rly Station Road	TRIVANDRUM 695001	32 27

Printed at Seema Offset Press, Delhi, India